MONTANA MARIAS BASIN RAINSTORM, JUNE 16–17, 1948

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INTRODUCTION

Heavy rainstorms are an important part of the climatology of an area; the study of heavy rainstorms is essential for sound development of agriculture, irrigation, power, flood control, or many other projects. This is particularly true when the storm produces greater precipitation for a given area than any previously recorded.

Such a record-breaking rainstorm occurred in the Marias Basin in Montana on June 16–17, 1948. Precipitation amounts from this single storm far exceeded previous records for an area of about 1,000 square miles in the storm center; the entire storm covered nearly 10,000 square miles. Devastating floods resulted and peak stream flows far exceeded previous high records at many points. Because of this storm's unusual importance to that part of Montana, special surveys and studies were made and others are in progress. It is the purpose of this paper to summarize briefly some of the more important aspects of the storm, including the distribution of rainfall, flooding and flood damage, meteorological features, and a comparison with other severe rainstorms recorded in the weather history of Montana.

RAINFALL DISTRIBUTION

Rainfall distribution from the storm of June 16–17, 1948, is shown in figure 1. Heaviest rainfalls were recorded in Pondera, Teton, Toole, and Glacier Counties, Mont., but unusually heavy precipitation was reported also in neighboring counties and in parts of the southwest corner of the Canadian Province of Alberta. Table 1 shows that the greatest 48-hour amount recorded was 9.10 inches at Dupuyer, about 14 miles southwest of Valier, Mont. Two-day totals of 7 inches or more were measured at several points. In some cases such as the 7.00+ inches measured at Ethridge ½ S, straight-sided containers known to be empty before the storm, filled and overflowed.

Table 2 lists records from five stations equipped with weighing rain gages, showing hourly amounts for the storm period. Although none of these gages was very close to either of the storm's apparent centers, the records tend to confirm reports by most observers that the storm was most intense from the afternoon of the 16th to the early morning of the 17th.

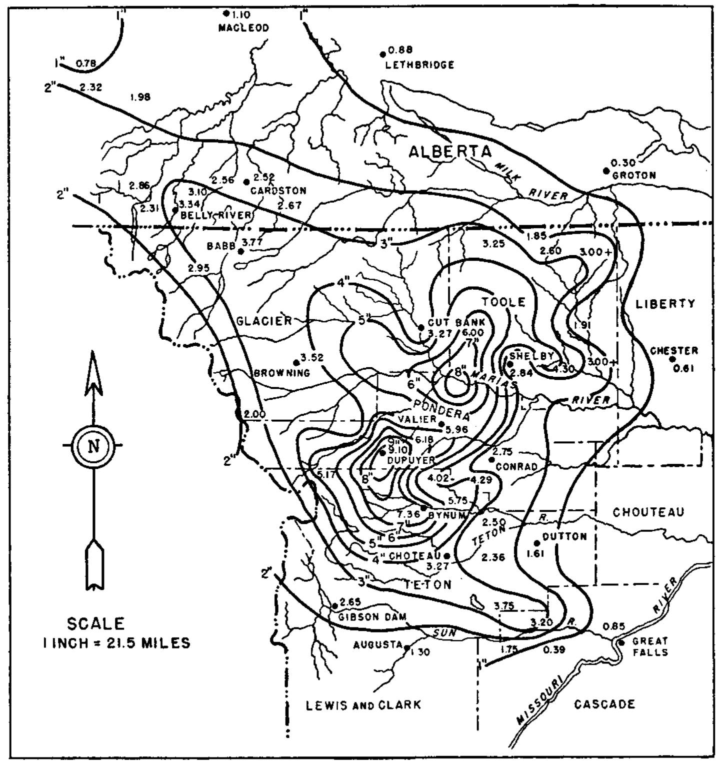

FIGURE 1.—Isohyetal chart for the Marias Basin rainstorm of June 16–17, 1948.

Areas within isohyets from 4 inches to 9 inches were estimated from figure 1 with a planimeter, and depth-area computations were made, following methods outlined by Foster [1]. These computations (table 3) show that the total volume of rainfall within the 4-inch isohyet was 15,248 in. mi.^{2}, or over 35,000 million cubic feet. This enormous quantity of water, coming after more or less continuous rains over the area during the preceding 5 or 6 weeks, resulted in the high discharges and floods discussed in the next section.

TABLE 1.—*Precipitation amounts, June 16–17, 1948*

WEATHER BUREAU COOPERATIVE CLIMATOLOGICAL STATIONS †

	Latitude	Longitude	Elevation (feet)	Precipitation (inches)
	° ′	° ′		
Augusta	47 28	112 23	4,071	1.30
Babb, 6 NE	48 56	113 21	4,461	3.77
Browning	48 34	113 01	4,366	3.52
Chester	48 30	110 57	3,100	.61
Choteau *	47 49	112 10	3,810	3.27
Conrad	48 10	111 58	3,519	2.75
Cut Bank Airport *	48 36	112 22	3,838	3.72
Dunkirk, 16NE	48 39	111 31	3,293	1.91
Dutton, 6 ESE *	47 52	111 35	3,711	1.61
Fairfield	47 37	111 58	3,983	3.75
Gibson Dam	47 36	112 47	4,000	2.65
Pendroy	48 04	112 18	4,264	4.02
Shelby *	48 31	111 51	3,276	2.84
Sherburne Lake	48 50	113 31	4,900	2.95
Summit *	48 19	113 21	5,213	2.07
Sun River, 5 SW	47 28	111 45	3,525	.39
Valier	48 18	112 15	3,800	5.96

RESULTS OF SURVEY OF STORM AREA **

	Latitude	Longitude	Elevation (feet)	Precipitation (inches)
Bynum	47 59	112 19	3,971	7.36
Bynum, 3 NE	48 00	112 15	‡3,800	5.75
Choteau, 4 NE	47 51	112 07	‡3,700	2.12
Choteau, 6 E	47 49	112 04	‡3,700	2.36
Collins, 9 WSW	47 52	111 59	‡4,600	2.50
Conrad, 10 SW	48 05	112 06	‡4,000	4.29
Cut Bank, 7½ W	48 37	112 31	3,996	4.90
Devon, 6 N	48 33	111 28	3,250	§3.00
Dunkirk	48 29	111 39	‡3,500	4.30
Dunkirk, 9 N	48 35	111 40	3,390	3.10
Dupuyer	48 12	112 30	4,200	9.10
Dupuyer, 8½ NW	48 14	112 35	3,878	5.10
Dutton, 11 E	47 48	111 42	‡3,700	.52
Ethridge, ½ S	48 32	112 07	3,543	7.00+
Ethridge, 4 N			‡3,500	6.00
Ferdig	48 56	111 33		3.00+
Fort Shaw, 3 N	47 30	111 48	‡3,600	3.20
Shelby, 5 W	48 31	112 05		5.00+

See footnotes at end of table.

TABLE 1.—*Precipitation amounts, June 16–17, 1948*—Continued

RESULTS OF SURVEY OF STORM AREA **—Continued

	Latitude	Longitude	Elevation (feet)	Precipitation (inches)
	° ′	°		
Shelby, 5 NW	48 36	111 58	‡3,250	5.75
Simms, 5 W	47 29	111 55	‡3,800	1.75
Sunburst, 8 E	48 53	111 40	‡3,650	2.60
Sweetgrass, 4 SW	48 56	111 59	‡3,800	3.20
Sweetgrass, 7 E	48 59	111 49		1.85
Valier, 5½ W	48 18	112 22	3,897	5.05
Valier, 16 W	48 17	112 35	‡3,800	7.00
Valier, 8 SW	48 13	112 22	‡3,900	8.40
Valier, 5 E	48 19	112 07	‡3,900	5.50
Williams, 7 N	48 23	112 05	‡3,800	8.50

CANADIAN STATIONS †

	Latitude	Longitude	Elevation (feet)	Precipitation (inches)
Beaver Mines	49 28	114 10	4,218	2.18
Belly River	49 03	113 41	4,550	3.34
Caldwell	49 10	113 28	4,000	2.56
Cardston	49 12	113 18	3,826	2.52
Carway	49 05	113 10	4,000	2.67
Cedar Cabin	49 05	113 52	4,200	2.31
Claresholm	49 54	113 49	3,395	1.42
Groton	49 12	111 20	3,000	.30
Lethbridge	49 38	112 39	3,018	.88
Macleod	49 44	113 24	3,128	1.10
Mountain View	49 09	113 36	4,325	3.10
Pincher Creek	49 28	113 58	3,758	1.98
Waterton Park	49 07	113 54	4,210	2.96

† Measurements made by trained observers using standard equipment. The Canadian data were generously supplied by the Canadian Meteorological Service.

*Hourly amounts are shown in table 2.

** Based largely on surveys of the storm area a few days after storm's end. Evaporation and other losses were not considered; however, amounts considered too doubtful to be useful were not included. Many amounts listed were supplied by persons owning private rain gages. No estimated amounts appear in the table except as noted at Devon, 6 N.

‡ Approximate.

§ Estimated from total for a longer period.

TABLE 2.—*Hourly precipitation amounts (in.)*

Date	Hour ending (MST) A. M. 1	2	3	4	5	6	7	8	9	10	11	12	P. M. 1	2	3	4	5	6	7	8	9	10	11	12	Daily sum	2-day sum, 5 p. m. 15 June–5 p. m. 17 June
	Cut Bank																									
15	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	0.26	0.19	0.01	----	----	----	----	----	----	
16	0.10	0.03	0.01	0.01	0.07	0.06	0.06	0.06	----	0.05	0.24	0.30	0.18	0.04	0.06	0.11	.07	.10	.07	0.05	0.13	0.25	0.22	0.18	2.45	
17	.19	.13	.08	.05	.16	.03	.02	----	0.04	.06	.03	.02	.02	.04	.02	----	----	----	.01	.01	.03	.01	----	----	.97	3.72
	Choteau																									
15	0.10	0.01	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	0.41	----	----	----	0.34	0.01	----	.87	
16	----	.02	0.01	0.01	0.03	0.01	----	----	0.01	0.01	0.01	0.04	----	0.23	0.41	0.26	0.19	.21	0.30	0.23	0.16	.16	.08	0.03	2.41	
17	.02	----	----	----	.01	----	----	----	.01	----	----	----	----	----	----	----	.03	.01	.01	----	----	----	----	----	.09	3.27
	Shelby																									
15	----	----	----	----	----	----	----	----	----	----	----	----	----	----	0.06	0.11	0.02	0.01	----	----	----	----	----	----	.20	
16	----	----	----	----	----	----	----	----	----	0.06	0.01	0.01	----	----	.22	.11	.16	.21	0.17	0.14	0.16	0.16	0.10	0.12	1.63	
17	0.08	0.13	0.23	0.19	0.17	0.23	0.06	0.01	----	.03	.04	.02	0.01	----	----	----	----	.01	----	----	----	----	----	----	1.21	2.84
	Dutton																									
15	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	0	
16	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	0.19	0.08	0.03	0.17	0.23	0.03	0.01	.74	
17	0.23	0.25	0.15	0.14	0.06	0.04	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	.87	1.61
	Summit																									
15	----	----	----	----	----	----	----	----	----	----	0.03	0.12	0.01	0.04	0.08	0.12	----	----	----	0.04	0.01	----	----	0.05	.50	
16	0.06	0.04	0.10	0.20	0.10	----	0.18	0.02	0.05	0.15	.05	.03	.02	----	.04	.01	0.05	0.06	----	----	.04	0.05	0.15	.06	1.46	
17	.14	.11	.04	.03	.02	0.04	.06	.09	----	----	----	.03	.02	----	----	----	----	----	----	.03	----	----	----	----	.61	2.07

TABLE 3.—*Depth-area computations for rainstorm, June 16–17, 1948*

Isohyet (inches)	Area enclosed (miles) [2]	Net area (square miles) between isohyets	Average depth between isohyets (inches)	Rainfall volume		Average depth (inches)
				Increment (in. mi.²) between isohyets	Accumulated (in. mi.²)	
9	46	46	9.05	416	416	9.05
8	128	82	8.5	697	1,113	8.7
7	377	249	7.5	1,867	2,980	7.9
6	770	393	6.5	2,554	5,534	7.2
5	1,575	805	5.5	4,427	9,961	6.3
4	2,750	1,175	4.5	5,287	15,248	5.5

FLOODING AND DAMAGE

The U. S. Geological Survey determined the peak discharge of the Marias River near Shelby, Mont., to be at the rate of 15.4 second feet per square mile, or 40,200 c. f. s. at about 0200 MST, June 18, as compared to the previous peak of 29,500 c. f. s. recorded in 1907. According to the Army Engineer and Geological Survey, flood stages were higher in 1908 several miles east of Shelby downstream, but in the Shelby area, there is no record of the river ever having been as high. Reflecting the fact that most of the storm area was located upstream from Shelby, the peak at Brinkman, downstream from Shelby, was at the rate of about 8 second feet per square mile, or 51,000 c. f. s., slightly less than the peak in the flood of 1908. At many points southwest of Shelby, peak stream flows far exceeded previous high records. Peak discharge rates on some Marias tributaries were very high, exceeding 100 second feet per square mile in some drainages. Some preliminary Geological Survey data for the vicinity of Valier show that Lone Man's Coulee had a peak discharge of 1,820 c. f. s. from an area of 11.4 square miles; Cartwright Coulee, 3,580 c. f. s. from an area of 21.8 square miles; Laughlin Coulee, 820 c. f. s. from an area of 8.4 square miles; and Miller's Coulee, 197 c. f. s. from an area of 1.7 square miles. About 4 miles south of Valier, one 53-acre area produced a peak runoff of 21.6 c. f. s. These drainage areas near Valier total only about 42 square miles, but because they were near the storm center, their discharge rates give some indication of the storm's intensity.

Near Dupuyer, runoff rates were somewhat lower, probably because storm intensity seems to have diminished west of that point. Blacktail Creek, with a drainage area of 63 square miles, had a peak discharge of 4,680 c. f. s., and Dupuyer Creek, draining about 135 square miles, had a peak of 7,800 c. f. s. On the Dry Fork of the Marias River north of Conrad, draining 253 square miles, the peak was determined to be approximately 13,000 c. f. s. These runoff determinations appear to confirm the location of the storm centers in the general areas described in the preceding section.

Stream flows were abnormally high in other areas of the storm, which extended into southern Alberta almost as far north as McLeod. However, flooding in these sections was not quite so severe as around Valier and Dupuyer. The Dominion Water and Power Bureau reported that Lee Creek at Cardston reached the highest discharge in forty years, and at least local flooding was experienced on all streams within the storm's boundaries. Decided peaks were observed by the Geological Survey on both Milk and Sun Rivers (which lie north and south, respectively of the Marias Basin) but serious flood levels were attained only in the Marias (including Teton River) Basin.

Considerable damage was sustained by basement and street flooding in and near the storm's center, severe damage was inflicted to road networks and bridges in Pondera and Teton Counties, and much crop land flood damage resulted in the entire storm area. The U. S. Army Engineers [2] which conducted a thorough survey of damages from this flood, estimated total losses and damage sustained at $1,445,758, in spite of the sparse population and limited development near the river. In all, the Army Engineers estimated that about 28,000 acres of crop land were flooded. No loss of life was reported.

A timely warning issued on the morning of June 17 by the Weather Bureau alerted the river basin from Shelby to the Missouri River confluence at Loma, and Army Engineer, State Police, and Highway personnel were instrumental in aiding persons at Loma and other points to take precautions for safeguarding life and property.

SYNOPTIC FEATURES

The storm which produced the record-breaking rainfall and the severe flooding described in preceding sections had several interesting synoptic features. As is generally the case with unusually heavy rainstorms, a number of rain-producing factors appear to have been involved. The interrelationships among these factors are, of course, complex and the following paragraphs are intended only to point out some of the more important phases.

1. The storm began during the day on June 16 over most of the affected area, generally with thunderstorms. The thunderstorm condition changed gradually to one of moderate to heavy rain. Storm intensity began to decrease early on the 17th, and by late afternoon diminished to light and scattered showers. The surface weather map for 0130 EST June 17 is shown in figure 2. The approximate area of the heavy rain is circled on the chart. The strong High in south-central Canada had maintained itself for several days, drifting gradually southward to the position shown. During the same period pressures fell gradually in northern Wyoming and northern Utah.

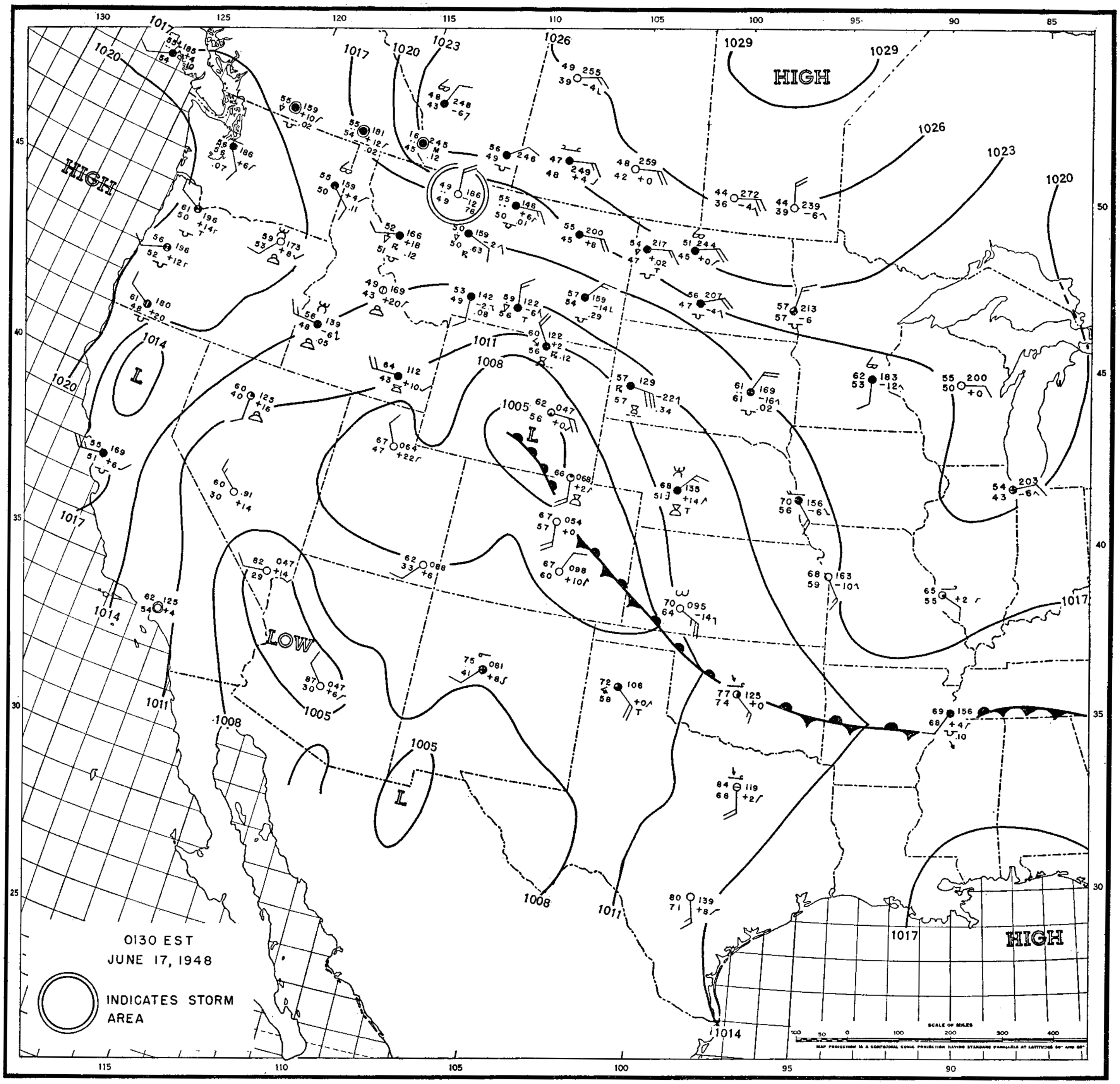

Figure 2.—Sea level weather map for 0130 EST, June 17, 1948. The circle in northern Montana indicates the rainstorm area.

The resulting increase in the pressure gradient caused easterly winds of 25 to 30 miles per hour in the lower levels of the atmosphere over western Montana on the 16th and early on the 17th. Figure 3 shows easterly winds near 5,000 feet above sea level, or about 1,000 feet above the surface of the storm area at 2300 EST, June 16, and figure 4 for the same time shows a tendency for easterly winds even at about 10,000 feet above sea level. This broad current from the east was conditionally unstable and relatively very moist (fig. 5). Substantial amounts of rainfall almost invariably occur along the eastern slopes of the Divide in connection with easterly upslope winds.

2. On the 16th, there existed an area of frontogenesis over central Wyoming between the easterly current of cold air to the north, and a very warm and moist southerly current over the Plateau. The 700- and 850-mb. charts for 2300 EST June 16 (figs. 3 and 4) show that the warm

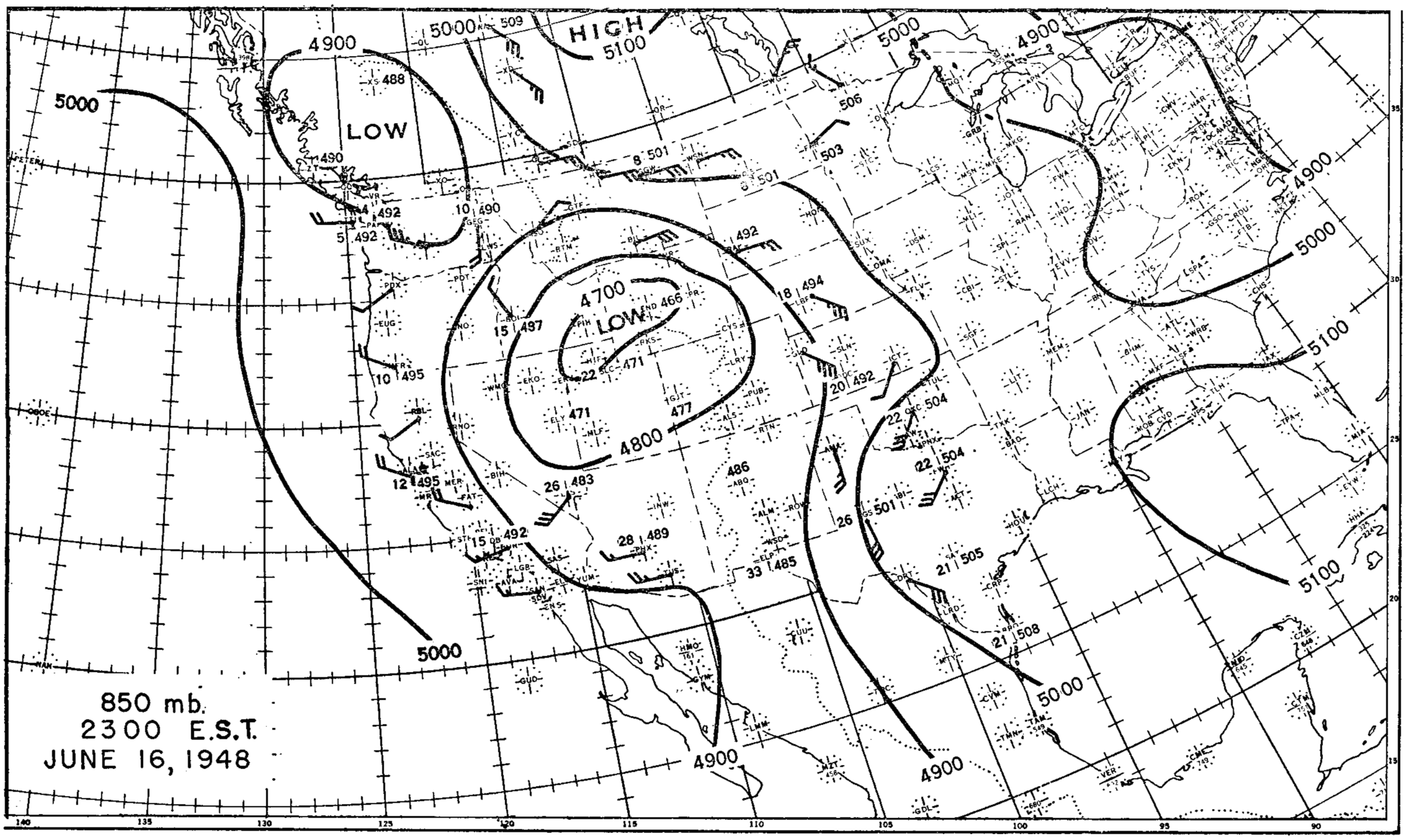

FIGURE 3.—850-mb. chart for 2300 EST, June 16, 1948.

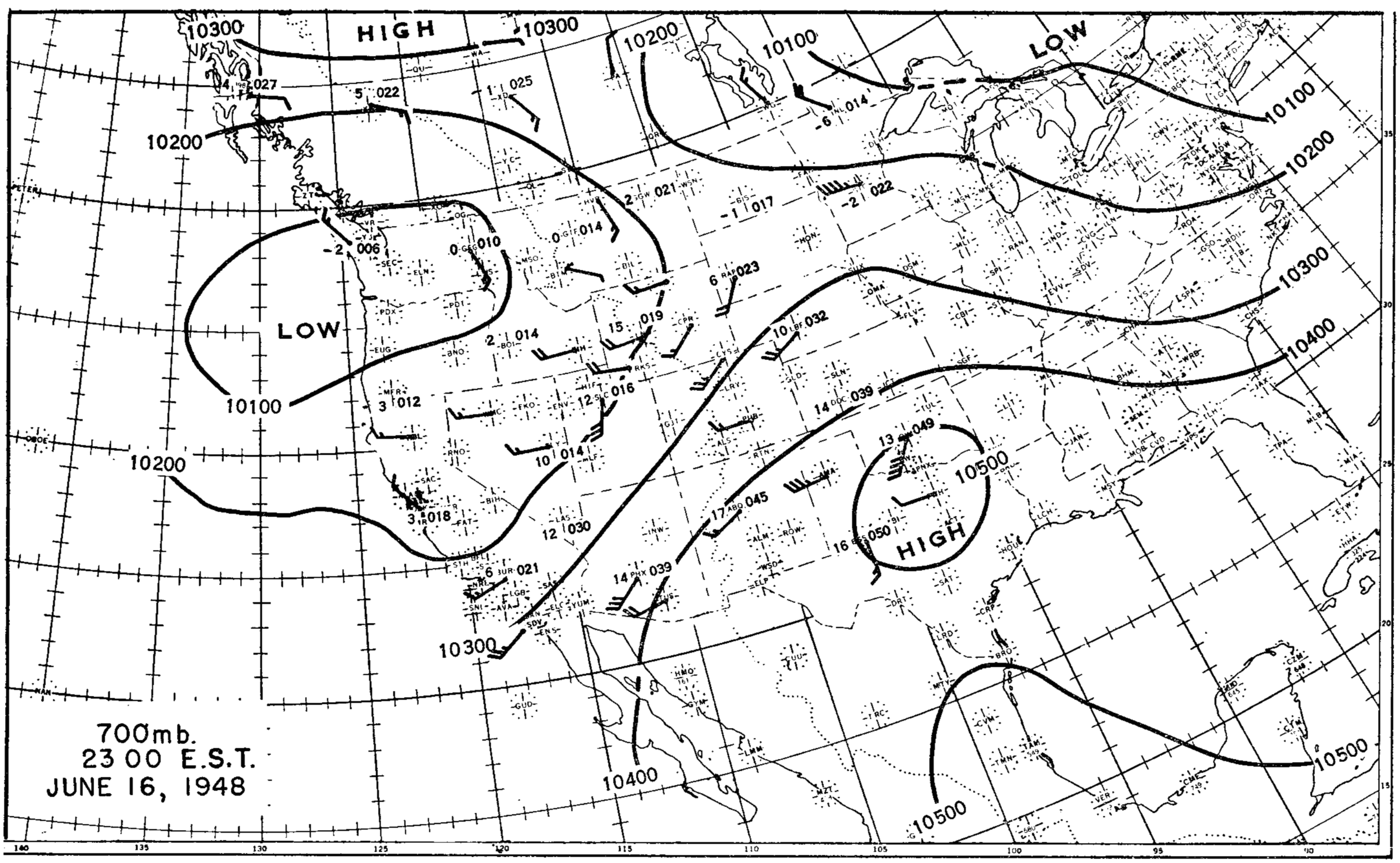

FIGURE 4.—700-mb. chart for 2300 EST, June 16, 1948.

current curved cyclonically aloft as it was forced to rise over the cold easterly current in western Montana. This condition persisted apparently for more than 24 hours, with weakening beginning to be evident on the 1100 EST June 17 charts.

3. The radiosonde observations for 1100 EST and 2300 EST June 16 and 1100 EST June 17 at Great Falls (fig. 5), indicative of conditions in the storm area, showed that conditional instability increased, apparently, as the storm got under way and continued at Great Falls in varying degree for several days.

4. A marked zone of convergence existed over northwestern Montana between the easterly winds near the surface east of the Divide, and the light westerly to southerly winds west of the Divide. The surface convergent pattern is particularly well-defined over the storm area in figure 2. Winds show this convergence also at the 850-mb. (fig. 3) and 700-mb. (fig. 4) levels. Normally, horizontal convergence in the upper air may be expected in regions of sharp cyclonic curvature, and such curvature is apparent throughout the storm at the 700-mb. level (fig. 4).

It appears, then, that four rain-producing factors operated in the areas of heaviest rainfall: (1) The orographic effect of the Continental Divide on the easterly current at lower levels; (2) warm, moist air overrunning the easterly current; (3) conditional instability; and (4) convergence. Both conditional instability and convergence seem likely to have been involved at first, as the storm began with heavy thunderstorms. The heaviest rains were observed during the evening of the 16th, and it is on the 2300 EST June 16 charts that the upslope and convergent patterns appear best developed. Based upon measured rainfall totals, the combined operation of all factors was apparently most intense near Dupuyer, where 9.10 inches fell. It is interesting to note that Dupuyer is only about 25 miles east of the Divide, and that the plain rises rapidly to the summit of the Divide west of that point.

While all four factors were present during the storm, the one most concentrated over the area appears to have been convergence. Conditional instability was general over western Montana both before and after the storm, and its release therefore seems to have depended on the operation of the other factors. The easterly current near the surface of course contributed to the convergent pattern at lower levels, and a good supply of moist air aloft was essential for heavy rainfall. The upslope effect was very important, particularly in adding the lifting of the cold air at least partly to the lifting of the overrunning moist air aloft. With a gradually increasing pressure gradient producing upslope winds, the air masses involved being moist and conditionally unstable, convergence being present at the surface and aloft, and a moist warm current overrunning an already rising moist cooler current at the surface, very heavy rains were the natural result over the area where these factors combined most effectively.

COMPARISON WITH OTHER MONTANA RAINSTORMS

It is interesting to note that during the 40-odd years for which records on a reasonably State-wide basis are available for Montana, nearly all record-establishing rainstorms occurred in June. The Springbrook storm of June 17–21, 1921; the Warrick storm on June 6–8, 1906; and the Evans storm on June 3–7, 1908, are outstanding examples. Studies of the Springbrook and Warrick storms [3] and data for the Evans storm [4] have been published.

From available data, it appears that both Warrick and Springbrook storms covered larger areas with greater precipitation depths than the June 1948 storm, however, both these storm centers were located over 200 miles east of Pondera and Teton Counties, at elevations averaging

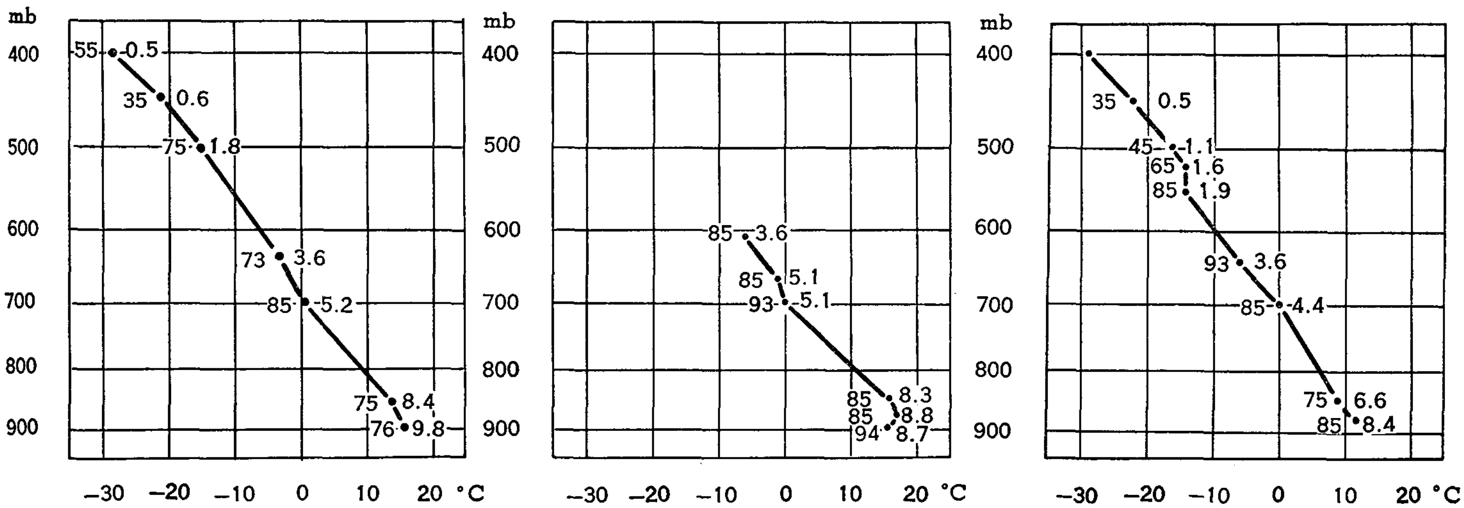

FIGURE 5.—Upper air soundings at Great Falls, Montana. (a) 1100 EST, June 16, 1948; (b) 2300 EST, June 16, 1948; (c) 1100 EST, June 17, 1948.

over 1,000 feet lower. The Evans storm of 1908 covered a much smaller area, although its duration was 5 days as compared to less than 2 for the 1948 Dupuyer storm. Precipitation totals and durations at the centers of the four storms are listed:

Storm	Precipitation: Total (inches)	Precipitation: Duration (hours)
Warrick, June 6–8, 1906	13. 3	54
Evans, June 3–7, 1908	10. 1	120
Springbrook, June 17–21, 1921	[1] 15. 1	108
Dupuyer, June 16–17, 1948	9. 1	36

[1] 10.5 inches in 6 hours.

A detailed comparative study of the four rainstorms is beyond the scope of this article, but it may be worthwhile to point out some interesting similarities as well as distinct differences revealed by an examination of the surface weather maps for the storms. All four storms were associated with unusually slow moving low-pressure centers lying in pressure troughs extending north-northwestward. The low-pressure center in 1948 lay to the south of Montana and deepened very little as it moved slowly eastward. But in the 1906, 1908, and 1921 storms, the low centers moved across Montana and deepened by large amounts. The high-pressure center advancing from the north, which was an important feature of the 1948 maps, was not present on the 1906, 1908, and 1921 maps. As in the 1948 storm, the air to the east of the low-pressure trough in the three earlier storms, warm and moist and apparently of Gulf origin, flowed northward along the eastern slopes of the Continental Divide and overran the cooler air to the north. This cooler surface air, flowing from the east moved upslope north of the cyclonic center. Thus, it seems that the rain-producing factors operating in the 1948 storm had been present in varying degrees also in the 1906, 1908, and 1921 storms.

Of course, all four storms produced widespread and damaging floods. With the exception of slight overlapping of boundary areas of the 1906 and 1921 storms, all four were confined to independent sections of Montana. Although other areas east of the Divide have had heavy, flood-producing rainstorms, these four are at the top of the list of those recorded in Montana.

CONCLUSIONS

Climatological records indicate that heavy rainfall over Montana is likely to occur most frequently between May and August, with a peak in June. Since temperature contrasts between air masses over Montana are often large in June, and air masses, particularly aloft, are capable of carrying much larger quantities of water vapor than during earlier months, slowly moving disturbances in June may be expected to produce heavy rains. During May, even though disturbances, and temperature differences between air masses, may be more marked than in June, only infrequently does water vapor content of the air reach the heavy rainfall-producing quantities possible in June. On the other hand, while water vapor content continues to increase on the average until mid-summer, frontal differences and disturbances become weaker, and later heavy rains appear more likely to be local in character, and to depend chiefly upon convection processes.

Unfortunately, it is not possible to estimate where or when a storm comparable to the one of June 16–17, 1948, will visit Montana again. However, given the right combination of meteorological factors, storms of similar—or even greater—magnitude may be expected in future years. That this combination of storm-producing elements will occur again seems safe to assume; it has happened at least four times in the last 50 years, not counting several lesser but also severe storms during the same period. Such occurrences demonstrate the damaging capacity of rainstorms, and sound long-range development of the area seems to require planning which includes calculation of maximum rainstorm possibilities. Fortunately, studies have been made of many major storms, and long-range development planning is making ever-increasing use of such data.

ACKNOWLEDGMENTS

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